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HIGH STRENGTH DIMENSIONALLY STABLE CORE

Field of the Invention

This invention relates to paperboard, paperboard cores and tubes, and to a method for making cores and tubes.

Background of the Invention

In the manufacture of paper, paper is wound onto cores. Cores are conventionally manufactured from laminated, spirally wound paperboard. It is important that cores have sufficient crush strength. Dimensional stability of cores is also important in roll handing operations.

Moisture content in paper varies considerably from grade to grade depending on the manufacturing process. Similarly, paperboard cores are made at different moisture levels, depending on the absorption characteristics of the paperboard from which it is made and the adhesive used to glue the board layers to form a laminated core. As a result, in the winding of paper onto cores, there is typically a moisture content difference between the paper and the core. A difference in moisture content between the paper and core causes moisture to migrate. Moisture migration from the core to the paper and vice versa can cause corrugations and wrinkling in the paper, and in some cases core bursts, resulting in paper losses.

Papermills today make wide paper rolls by winding different webs of paper onto a single core. Often, the different webs have different moisture contents, aggravating moisture migration problems. Further, these wide rolls require high strength cores to support the substantial weight of the paper.

Summary of the Invention

It is an object of the invention to provide a high strength, dimensional stable paperboard core, with improved resistance to moisture

migration. It is a further object of the invention to provide a high strength, water resistant paperboard that has utility in the fabrication of such cores.

The core of the invention is manufactured from spirally wound paperboard having improved water resistance. The paperboard is made from a standard paperboard furnish. A preferred furnish comprises a mixture of 25-70% doubleliner kraft ("DLK"), and 25-70% recycled corrugated containers ("OCC"), and 30-50% recycled cores and/or other cores waste ("corebale"). The furnish should have a freeness of 150-275 CSF. The furnish is modified by adding 5-60 lbs/ton alum, 3-40 lbs/ton of liquid size, and 16-50 lbs/ton modified cationic starch. Other additives may optionally include 0.2 - 1. lbs/ton microparticle silica, and/or 2-8 lbs/ton of a dry strength agent, but are not required.

A more preferred formulation has a paperboard furnish, 4-40 lbs of alum per ton of furnish (more ideally 4-12 lbs/ton of alum); 3-12 lbs of liquid size per ton of furnish, and 30-40 lbs of cationic starch per ton of furnish.

It has been discovered that the combination of alum and a liquid size substantially improves water resistance. The alum improves drainage and helps reduce the swelling of wood fibers. Wood fibers swell when absorbing water. Significant drying energy or time is required to remove moisture absorbed by the fiber. Desirably the resulting paperboard has water absorption less than 400 cgs.

A suitable alum product is aluminum sulfate solution available from General Alum & Chemical Corporation, Holland, Ohio.

A preferred liquid size is Ultra-pHase® cationic dispersed size manufactured by Hercules Incorporated, Wilmington, Delaware.

The modified cationic starch improves strength, especially in combination with alum. Cationic starch also contributes to drainage, thereby allowing for a reduction in the quantity of alum used. A preferred starch product is Penford Topcat 776 cationic additive, manufactured by Penford Products Co., Cedar Rapids, Iowa. Other suitable starch products are Avebee Amylofax 3300C and Amylofax-HS.

The microparticle silica is added to improve the drainage in the paperboard making process. A preferred microparticle silica is Nalco 8692 Papermaking Aid, an aqueous dispersion of an inorganic hydrous oxide microparticle, manufactured by Nalco Chemical Company, Naperville, Illinois. Other microparticle silica products may be used as well.

The dry strength agent improves strength and contributes somewhat to improvement in water resistance. Suitable dry strength agent is Callaway 911 dry strength agent, manufactured by Vulcan Performance Chemicals, Birmingham, Alabama. However, most dry strength agents are expensive additives and for this reason are less preferred.

The forgoing optional additives are selected and added as required to produce the required properties of the core. For example, if a high strength is not required, one could use little or no starch or dry strength agents. Other additives could be used, for example a wet strength agent.

The modified furnish is manufactured into paperboard by known manufacturing techniques, such as fourdrinier or multiple cylinder papermachine, to produce a finished paperboard having a basis weight of 50-142 lbs per 1000 sq/ft., a caliper of about 0.013 to .041 inches, a density of 0.7 to 1.0 g/cm^3 and a moisture content of between about 3-6 percent. The moisture content of the cores preferably should be as close as possible to the moisture content of the paper to be wound onto the cores.

The paperboard is then wound with conventional core machinery to form paperboard cores having between 3-32 plies. For example, one embodiment of the invention comprises high strength cores for paper rolls, which have 20-32 plies. Another application of the invention is for cores for adhesive tape and other small tube applications, which have 3-7 plies. In smaller cores made in accordance with this disclosure have a lower core crush variability due to humidity and improved dimensional stability. The preferred adhesive used in winding the cores is polymer base, such as latex or polyvinyl alcohol; however, other adhesives like dextrins may be used.

Testing on the cores made in accordance with the foregoing exhibited increased crush strength, and increased water holdout. The cores exhibited reduced moisture carry over, and low core length shrinkage. Other benefits include reduced core warpage and less variability in core inner and outer diameter.

Detailed Description of Preferred Embodiments

Examples of the improved high strength, dimensional stable cores of the invention are provided as follows:

GP1 Standard

The furnish comprised: 950 lbs DLK, 1,000 lbs OCC and 1,400 lbs corebale. Paperboard was manufactured from the furnish on a conventional board machine. The resulting paperboard had a caliper of about 0.02 inches and a basis weight of about 80 lbs/1,000 square feet. The core was wound in conventional process, having a lead-in ply and 30 structural plies formed with the above furnish. The cores had an internal diameter of 3.025 inches and a wall thickness of 0.66 inches.

Paperboard and cores were tested for water absorption and strength. The paperboard had a water absorption of less than about 950 - 1150 cgs based on the amount of water absorbed by a 6" x 6" paper board sample submerged in a water bath for 10 minutes (Tappi test method T491-om-99). The paperboard had a ZDT bond strength of 100 "Z"directional internal bond strength of board tested on a ZDT tester. Core crush strength was 800-850 lbs on a 4" length of core, and Dynamic load strength of 26-29 lbs/4" section. The moisture content of the core was 9-11%.

Example P1

The same paperboard and cores as in Example GP1 were manufactured, except that the following constituents were added to the furnish:

Callaway 911dry strength agent @ 6 lbs/ton dry weight

Ultra-Phase liquid size @ 31 lbs/ton dry weight

Alum was varied between 20 and 60 lbs/ton dry weight

Paperboard and cores were tested for water absorption and strength. The paperboard had a water absorption of less than 400 cgs based on the amount of water absorbed by a 6" x 6" paper board sample submerged in a water bath for 10 minutes. The paperboard had a ZDT bond strength 105-112 - "Z"directional internal bond strength of board tested on a ZDT tester. Core crush strength was 1135 lbs on a 4" length of core, and Dynamic load strength of 35.2 lbs/4" section. The moisture content of the core was 7.86%.

Example P2

The same paperboard and cores as in Example GP1 were manufactured, except that the following constituents were added to the furnish:

Callaway 911dry strength agent @ 6 lbs/ton dry weight

Ultra-Phase size @ 16 lbs/ton dry weight

Avebe Amylofax-HS starch was varied between 33 and 50 lbs/ton dry weight.

Alum was varied between 20 and 60 lbs/ton dry weight

Paperboard and cores were tested for water absorption and strength. The paperboard had a water absorption of less than 300 cgs based on the amount of water absorbed by a 6" x 6" paper board sample submerged in a water bath for 10 minutes. The paperboard had a ZDT bond strength 112-124 - "Z"directional internal bond strength of board tested on a ZDT tester. Core crush strength was 1238 lbs on a 4" length of core, and Dynamic load strength of 36.3 lbs/4" section. The moisture content of the core was 8.43%.

Example P5

The same paperboard and cores as in Example GP1 were manufactured, except that the following constituents were added to the furnish:

Penford Topcat 776 cationic starch @ 30 lbs/ton dry weight

Ultra-pHase size @ 3 lbs/ton dry weight

Alum @ 4 lbs/ton dry weight.

Paperboard and cores was tested for water absorption and strength. The paperboard had a water absorption of less than 700 cgs based on the amount of water absorbed by a 6" x 6" paper board sample submerged in a water bath for

10 minutes. The paperboard had a ZDT bond strength 125-141 - "Z"directional internal bond strength of board tested on a ZDT tester. Core crush strength was 1299 lbs on a 4" length of core, and Dynamic load strength of 36.5 lbs/4" section. The moisture content of the core was 7.23%.

Example P5A

Example P5A was prepared in the same manner as Example P5, with the following modifications to the alum and size constituents:

Ultra-pHase size @ 12 lbs/ton dry weight

Alum @ 4-5 lbs/ton dry weight.

Attached as Figures 1-10 are graphs that summarize comparative testing on the cores of examples GP1, P1, P2 and P5. Figs. 1-7 show the effects of ambient air drying on standard core samples made in accordance with this disclosure, namely P1, P2 and P5 as compared to a standard core sample GP1. Uniformly, the samples P1, P2 and P5 exhibit significantly less variability than the standard GP1 core. Conventionally cores must be dried either by ambient air drying or by oven drying to reach a target moisture content and other criteria specified by the mill, i.e., the cores must be cured prior to use. Ambient drying takes time and storage space. Oven drying requires a capital expenditure plus energy. Cores made in accordance with this disclosure reduce or eliminate these costs.

Fig. 1, shows that core moisture varies considerably with the GP1 standard core. Core samples P1, P2 and P5 showed considerably less moisture variability. Core sample P5 showed nearly nil core moisture variability.

Fig. 2 shows the effect of ambient drying on core crush strength. The GP1 standard core is typical of conventional cores. Crush strength varies considerable as the core cures. Also, crush strength increases with time from its initial green strength. In contrast the core samples P1, P2 and P5 performed considerably better exhibiting less variability and less cure time. Also, the P5 core exhibited superior crush strength.

Fig. 3 illustrates the effect of ambient drying time on dynamic load strength. The dynamic load strength test simulates the dynamic loads that cores experience when being wound with paper or other material. As with core crush strength, core sample GP1 standard exhibited considerable variability, while core samples P1, P2 and P5 exhibited comparatively less variability.

Fig. 4 shows the effect of ambient drying on length shrinkage. Core samples P1, P2 and P5 show less variability as compared to GP1 standard.

Fig. 5 shows the effect of ambient drying on core warp. Core warp is measured as the differential height between high and low spots on the core, when the core is held in a level, horizontal position. The Fig. 5 graph shows considerable variability in warp in the GP1 standard core as it cures. Core samples P1 and P5 exhibit considerable less warp during the same period.

Fig. 6 illustrates the effect of ambient drying time on core outer diameter, and Fig 7 shows the effect on core inner diameter. The graphs show comparatively less variability in diameter in samples P1, P2 and P5, as contrasted with the GP1- standard.

Fig. 8 shows the effect of oven drying on core moisture. Core samples P1, P2 and P5 had lower moisture contents than the GP1 standard core.

Fig. 9 shows the effect of oven drying on core moisture on core crush strength and dynamic load strength. In both cases core sample P5 exhibited increased core crush strength.

Fig. 10 shows moisture migration from the core to the paper. Paper of a uniform, low moisture content (1.5%) was wound onto the core samples, and held for a period of 7 days to 3 weeks time. The paper was then un-wound and the moisture content of the paper was measured at various locations measured radially from the core. The graph shows that there is little difference between core samples on paper located radially more than 3 inches from the core. However, in the range of 3 inches to 0.5 inch radially from the core, the paper wound onto the GP1 standard core picked up more moisture

from the core (moisture migration), as compared to either the P1 or P2 sample cores. In the range of 0.5 inch and less radially outward from the core, the paper wound on to the GP1 standard core exhibited greater moisture migration to the paper as compared to the P2 core sample.

Further testing on Example P5A has shown strength improvements in addition to reduced variability and improved moisture migration resistance. The following Tables 1-3 compare properties of standard GP1 core samples (Table 1) with core samples having the same furnish as GP1 but with the additives of Example P5A (Table 2), and a conventional high strength core, designated GP1-X (Table 3). The GP1-X core is spirally wound from high strength Pori paperboard, available from Coresno AB, Finland. Pori board is considerably more expensive that the conventional paperboard used to make the GP1 standard. Specifically, the direct costs (material, setup and running) for GP1-X cores is approximately 26% greater than standard GP1 cores. In contrast, the P5A core direct costs is only marginally greater (approximately 3.5%) than the standard GP1 core.

Table-1 GP1 Standard Core

Ambient Drying Days		Inside Dia, inches	Outside Dia, Inches	Wall Thickness, Inches	Crush lbs/4"	% Moisture	Dynamic Load Kn-10cm
0	Avg	3.042	4.343	0.650	799	10.21	26
	Stdev	0.001	0.014	0.007	22	0.28	1
2	Avg	3.044	4.350	0.653	808	9.51	26
	Stdev	0.001	0.015	0.008	13	0.26	1
4	Avg	3.045	4.347	0.651	817	9.65	26
	Stdev	0.001	0.014	0.007	50	0.20	1
7	Avg	3.047	4.348	0.650	807	9.01	26
	Stdev	0.002	0.019	0.009	2	0.14	1
14	Avg	3.037	4.336	0.649	828	8.46	24
	Stdev	0.001	0.016	0.008	13	0.15	0

Table-2: Example P-5A Core

Ambient Drying Days		Inside Dia, inches	Out.Dia, Inches	Wall Thickness, Inches	Crush lbs/4"	% Moisture	Dynamic Load Kn-10cm
0	Average	3.024	4.354	0.665	1157	9.7	32
	Stdev	0.004	0.005	0.004	50	0.3	4
	n	5	5	5	5	5	5

Table-3 High Strength GP1-X Core

Ambient Drying Days		Inside Dia, inches	Out.Dia, Inches	Wall Thickness, Inches	Crush lbs/4"	% Moisture	Dynamic Load Kn-10cm
0	Avg	3.042	4.387	0.672	1201	12.58	37
	Stdev	0.001	0.003	0.002	9	0.18	1
2	Avg	3.042	4.388	0.673	1232	11.55	36
	Stdev	0.002	0.005	0.003	10	0.06	1
4	Avg	3.045	4.385	0.670	1247	11.82	37
	Stdev	0.001	0.005	0.002	3	0.09	1
7	Avg	3.055	4.385	0.665	1295	9.80	39
	Stdev	0.000	0.005	0.003	32	0.10	2
14	Avg	3.041	4.369	0.664	1366	9.01	40
	Stdev	0.001	0.003	0.001	47	0.58	1

The data of Tables 1-3 show that the cores made with comparatively low cost furnish with the additives of Example P5A, produce a core that with essentially no ambient drying has a crush strength that is substantially higher than the standard GP1 core and comparable to more expensive, high strength GP-1 cores. Dynamic load data for the P5A core is also significantly higher than the standard GP-1 core.

Tables 1-3 further show that the amount of ambient drying time necessary to reach a target moisture content is substantially lower in Example P5A cores. With essentially no drying time, the P5A core had a 9.7% moisture.

To achieve the same moisture content required at least 4 days for the GP1 standard core and 7 days for the GP1-X core. It is believed that the combination of alum and size improves weatherproof characteristics of the paperboard & a combination of alum and modified cationic starch facilitates more effective drainage and therefore improved drying and efficiencies on the paperboard machine as well.

The following Tables 4-6 compare properties of oven dried standard GP1 core samples (Table 4) with oven dried core samples having the same furnish as GP1 but with the additives of Example P5A (Table 5), and an oven dried conventional high strength GP1-X core (Table 6).

Table-4 GP1 Standard Core

Drying Temp. Deg F	Oven Drying Time Hrs		Inside Dia, inches	Out.Dia, Inches	Wall Thickness, Inches	Crush lbs/4"	% Moisture	Dynamic Load Kn-10cm
75	24	Average	3.042	4.343	0.650	799	10.2	26
75	24	Stdev	0.001	0.014	0.007	22	0.3	1
100	24	Average	3.042	4.342	0.650	814	9.2	25
100	24	Stdev	0.001	0.012	0.006	29	0.3	1
120	24	Average	3.041	4.340	0.650	810	8.2	25
120	24	Stdev	0.001	0.022	0.011	21	0.3	1

Table-5: Example P-5A Core

Drying Temp. Deg F	Oven Drying Time Hrs		Inside Dia, inches	Out.Dia, Inches	Wall Thickness, Inches	Crush lbs/4"	% Moisture	Dynamic Load Kn-10cm
110	24 hrs	Average	3.022	4.340	0.658	1180	7.2	36
		Stdev	0.004	0.004	0.003	50	0.6	3
		N	5	5	5	5	5	5

Table-6: High Strength GP1-X Core

Drying Temp. Deg F	Drying Time Hrs		Inside Dia, inches	Out.Dia, Inches	Wall Thickness, Inches	Crush lbs/4"	% Moisture	Dynamic Load Kn-10cm
75	24	Average	3.042	4.387	0.672	1201	12.6	37
75	24	Stdev	0.001	0.003	0.002	9	0.2	1
100	24	Average	3.042	4.380	0.669	1248	11.3	39
100	24	Stdev	0.001	0.002	0.001	12	0.2	2
120	24	Average	3.040	4.375	0.668	1255	9.8	38
120	24	Stdev	0.001	0.002	0.001	22	0.2	2

Tables 4-6 show that in the oven dried cores, the P5A core exhibits substantially higher crush strength and dynamic load strength than the standard GP1 core. The oven P5A cores had strength comparable to the more expensive GP1-X cores. In addition, the P5A cores had substantially lower moisture content after the same drying time, and a lower temperature, as compared to both the GP1 standard and GP-X cores.

While presently preferred embodiments of the invention have been herein described, it is to be appreciated that various changes, rearrangements and modifications may be made therein without departing from the scope of the invention as defined by the appended claims.